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Short Communication
Notes on Inflorescence Structure of *Boesenbergia* (Zingiberaceae)

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One-sided spiral arrangement of bracts is described in detail with comparison of distichous one in *Boesenbergia* (Zingiberaceae). Association among inflorescence structure, anther dehiscence patterns, and geographic distribution are discussed.

Key words: Zingiberoideae; inflorescence structure; distichous; one-sided spiral arrangement; Borneo

Boesenbergia O. Kuntze is a relatively large genus in the Zingiberaceae currently including about 80 species. Recent publications describing many new species (Smith 1987, Poulsen 1993, Larsen 1993, 1997, Cowley 1998, 2000, Saensouk & Larsen 2001, Sakai & Nagamasu 2006) indicate that others are yet to be described. *Boesenbergia* has been regarded as a well-defined genus characterized by the two-ranked (distichous) arrangement of the bracts and an inflorescence in which flowers open from the apex to the base (determinate). Within the family, these characteristic are known only in the closely related *Haplochorema* and probably in the more distantly related *Caulokaempferia*. *Boesenbergia* differs from those two genera in its concave labellum and small anther crest (Larsen & Smith 1972, Smith 1987).

During studies on the Zingiberaceae in the Lambir Hills, Borneo (Sakai & Nagamasu 1998, 2006), however, we found that in many species of *Boesenbergia* the bracts were arranged spirally on only one side of the inflorescence axis. Such an arrangement was first reported by Cowley (1988) for *B. bruneiana* Cowley. She referred to the arrangement only briefly, and believed it to be unique to the species. The feature is not uncommon in the genus, however, especially in Borneo. In this paper, we report on the association between inflorescence structure, anther dehiscence patterns and geographic distribution of 26 species of *Boesenbergia*. Additionally, the phylogenetic significance of these characters is discussed.

Two types of inflorescences

The two-ranked arrangement of bracts in *Boesenbergia* is commonly referred as distichous, but is not strictly so since the bracts overlap on one face of the axis but not on the other (Smith 1987). In most of the distichous species, the long inflorescence is exerted from the leaf sheath and the two-ranked arrangement is visible. The flowers open from apex to base, and alternately from right to left (Figs. 1A, 2A). Two vertical rows can be easily recognized, as shown by the thin lines on the rachis of the inflo-

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TABLE 1. List of species in which inflorescence structure was examined. Anther dehiscence patterns are classified into slit (anther thecae dehiscing throughtout length), short slit (thecae dehiscing by slits much shorter than thecae) and pore (dehiscing by pores).

Species	Inflorescence	Anther dehiscence*	Material examined
Indochina			
B. acuminata P.Sirirugsa	Distichous	Slit[Sr]	*Shimizu et al. 7917* (KYO, holo.)
B. curtisii (Bak.) Schltr.	One-sided	Pore	*Shimizu et al. 8032* (KYO)
B. longiflora (Wall.) Kuntze	Distichous	Slit	*Tanaka et al. 23015* (TI)
B. longipes (King & Prain) Schltr.	Distichous	Slit	*Maxwell 75-797* (AAU)
B. parvula (Wall. ex Bak.) Kuntze	Distichous	Slit[Sr]	*Sorensen et al. 3639* (AAU)
B. petiolata P.Sirirugsa	Distichous	Slit[Sr]	*Maxwell 74-631* (AAU, iso.)
B. plicata Holt.	Distichous	Slit[Sr]	*Charoenphol et al. 3638, 3691* (AAU)
B. prainiana (King ex. Bak.) Schltr.	Distichous	Slit[Sr]	*Charoenphol et al. 3987* (AAU)
B. pulcherrima (Wall.) Kuntze	Distichous	Slit[Sr]	*Kerr 9107* (C)
B. rotunda (L.) Mansf.	One-sided	Slit	*Maxwell 76-579* (AAU); *Larsen 10540* (AAU)
B. tenuispicata K.Larsen	Distichous	Slit[Sr]	*Larsen et al. 43446* (AAU, holo.)
B. trangensis K.Larsen	Distichous	Slit	*Larsen 44000* (AAU, holo.)
Borneo			
B. burttiana R.M.Sm.	One-sided	Slit	*Burtt 8325* (E, holo.)
B. burneiana J.Cowley	One-sided[C1]	Pore	*Dransfield 1136* (K, holo.)
B. flabellata S.Sakai & Nagam.	One-sided	Pore	*Sakai 399* (KYO, type); *Nagamasu 6728* (KYO)
B. grandifolia (Val.) Merr.	One-sided	Pore[V]	*Nieuwenhuis 939* (BO, lectotype)
B. grandis R.M.Sm.	One-sided	Slit[Sm1]	*Argent & Kerby 794* (E, holo.)
B. hosensis J.Cowley	One-sided	Pore[C2]	*Cowley 55* (E, holo.)
B. ischynosiphon S.Sakai & Nagam.	One-sided	Short slit	*Sakai 79, 81* (KYO)
B. lambirensis S.Sakai & Nagam.	One-sided	Pore	*Sakai 174* (KYO, holo.)
B. lyschitodies S.Sakai & Nagam.	One-sided	Pore	*Sakai 414* (KYO, holo.)
B. orbiculata R.M.Sm.	-**	Slit	*Poulsen 257* (AAU)
B. parva (Ridley) Merr.	One-sided	Pore	*Burtt & Martin 4706* (E), *Burtt & Woods B2489* (E), *Sakai 409* (KYO), *Nagamasu 6733* (KYO)
B. pulchella (Ridley) Merr.	Distichous	Slit	*Ridley s.n.* (K, type); *Kokawa & Hotta 563* (KYO)
B. stenophylla R.M.Sm.	One-sided	Pourous[Sm2]	*Burtt & Woods B2219* (E)
B. urceoligena A.D.Poulsen	One-sided	Short slit[P]	*Poulsen 251* (AAU, holo.)
B. variegata R.M.Sm.	One-sided	Slit	*Hansen 113* (C, holo.)

* Superscripts indicate that descriptions of the character states are based on the following literature; C1: Cowley (1998); C2: Cowley (2000); P: Poulsen (1993); Sm1: Smith (1987); Sm2: Smith (1979); Sr: Sirirugsa (1992); V: Valetom (1918).
** Inflorescence structure of *B. orbiculata* could bot be determined due to small numbers of flowers on an inflorescence.

rescence (large triangle) in Fig. 1A .

In contrast, other species of *Boesenbergia* have inflorescences with bracts arranged on one side. This type of inflorescence is often short, congested, and concealed within the leaf sheath. The bracts overlap on one side but not on the other. The view of the non-overlapping side easily causes misunderstanding that the bracts are arranged distichously, because only the two bracts at the end of each horizontal row are visible (Fig. 2B). On the other side, however, the bracts overlap considerably (Fig. 2C). The bracts are arranged as if a fusiform inflorescence with spirally arranged bracts were split vertically into two. The flowers again open strictly from the apex to the base, irrespective of which row the bract is in (Figs. 1B, C). Figs. 1B and 1C illustrate the overlapping side of the inflorescence. The thin lines in the large triangle indicate horizontal rows of flowers (circles), which are parts of the spiral.

Distribution of the two inflorescence types

We observed the inflorescence arrangement of 26 species of *Boesenbergia* from Indochina (Thailand,

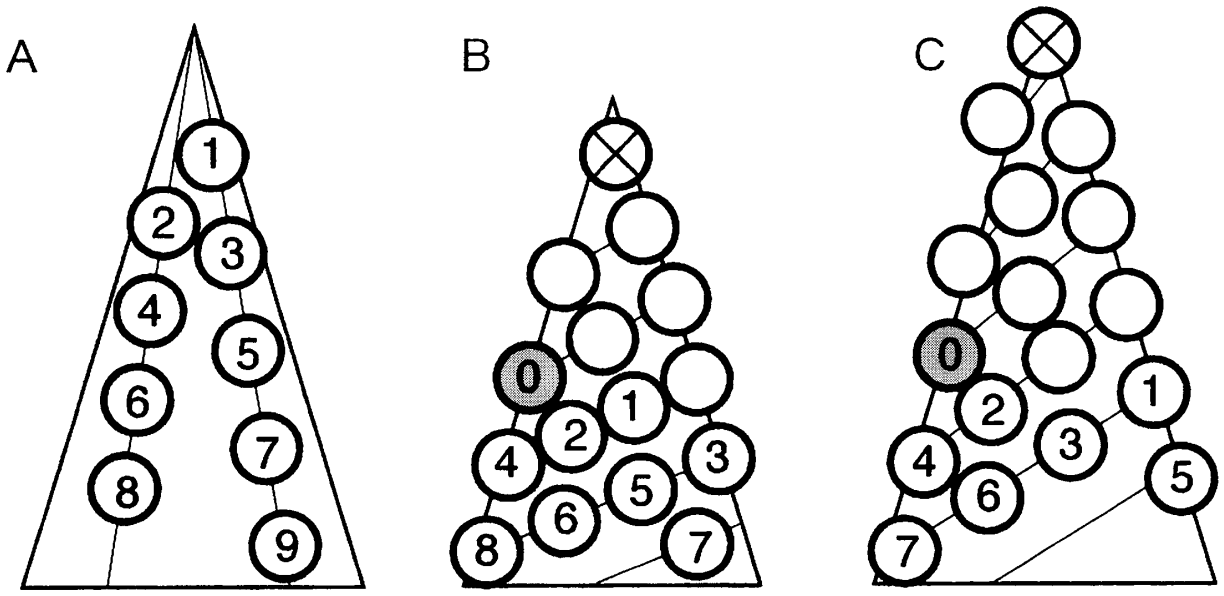

FIG. 1. Diagrams showing arrangement of flowers in inflorescences of *Boesenbergia*. Circles indicate flower location on rachis of inflorescence; inflorescence indicated by open triangle. (A) Distichous flowers in two vertical rows shown by thin lines. Numbers represent order of flowering within inflorescence. (B, C) Arrangement of flowers on *B. flabellata* (one-sided spiral, imbricate) based on spirit material (*Nagamasu 6728* - KYO). Numbers represent order of flowering estimated by size of flower buds. Circles with cross are aborted flowers, shaded circles indicate flowering. Thin lines under flowers show horizontal rows of spiral arrangement. (C) diagram of inflorescence shown in Figs. 2B and C.

Burma) and Borneo (Malaysia, Brunei). Since it is difficult to elucidate the spiral arrangement, especially in dried materials, we distinguished two types of bract arrangement: 1) distichous, and 2) densely imbricate and verticillate. In the former type, the flowers are arranged in two vertical rows (Fig. 1A), while in the latter, more than two flowers are arranged almost verticillate in the basal part of the inflorescence, but only on one side, and two vertical rows cannot be clearly recognized.

We also examined the correlation between inflorescence structure and anther dehiscence patterns. Variation in anther dehiscence has been recognized since Valeton (1918). The thecae of some species open by terminal pores, but in others the thecae dehisce throughout their length. The pores are not true pores in most species, because slits usually run downward from the pores on the inner face of each theca (Smith 1987). Rarely, the anthers dehisce by slits about half the length of the thecae. This may be an intermediate condition between slits and pores. Here we categorize anther dehiscence patterns into slits (anther thecae dehiscing throughout their length), short slits (thecae dehiscing by slits much shorter than thecae) and pores (dehiscing by pores).

Based on our observations, 11 of the 26 species we examined have distichous inflorescences, while 15 have an imbricate inflorescence. Interestingly, most species of *Boesenbergia* from Indochina have a distichous inflorescence, while most species in Borneo have an imbricate inflorescence (Table 1). Additionally, one-sided species include both slit and pore type anther dehiscence, but only slit type dehiscence is known in the distichous species. The correlation suggests that bract arrangement is an important character in the intrageneric classification of *Boesenbergia* and for considering the taxonomic limit of the genus.

Recent molecular studies have questioned the monophyly of *Boesenbergia*. Kress *et al.* (2002) studied the phylogeny of the entire family and recognized two clades in *Boesenbergia*; one with *B.*

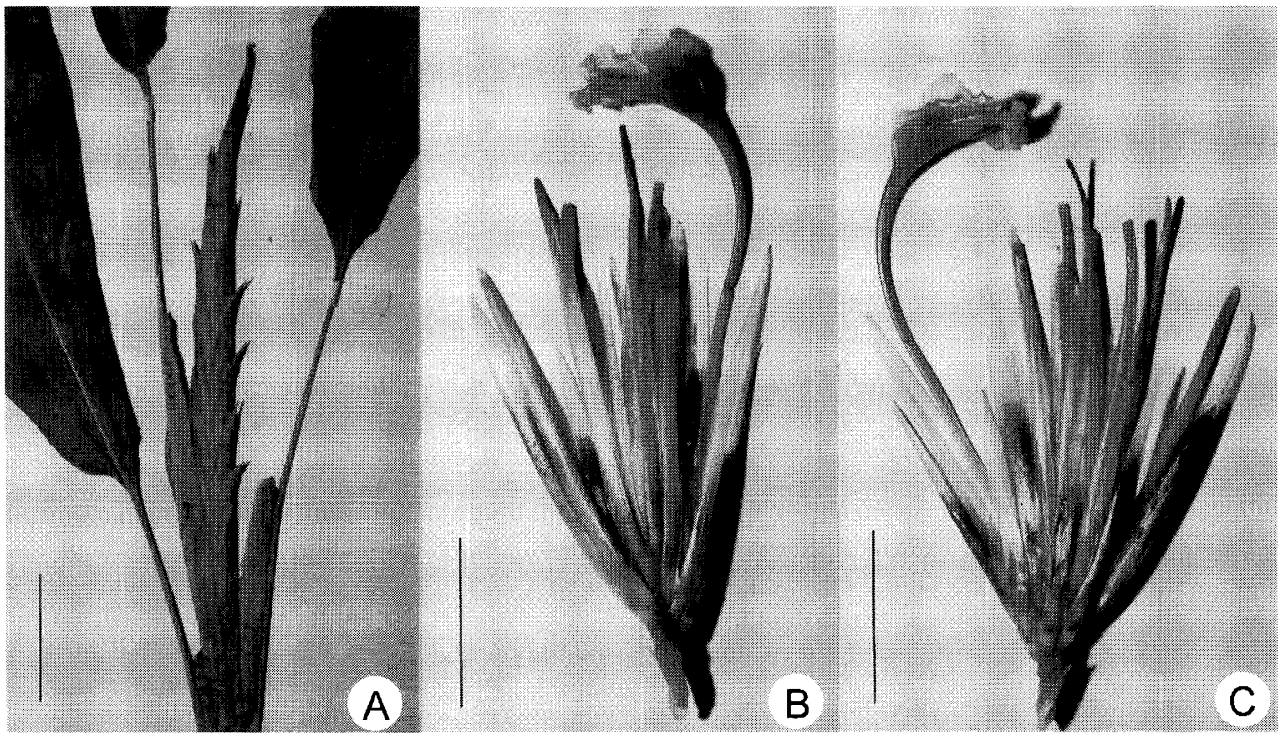

FIG. 2. Photographs of inflorescences with distichous (A) and one-sided spiral arrangement of flowers (B, C), bars = 2 cm. (A) *Boesenbergia. pulchella*, herbarium sheet (*Kokawa & Hotta 563* - KYO). (B, C) *B. flabellata*, sprit material (*Nagamasu 6728* - KYO).

pulcherrima (Wall.) Kuntze and *B. longiflora* (Wall.) Kuntze (= *Curcumorpha longiflora* (Wall.) A.S.Rao & D.M.Verma), and the other with *B. rotunda* (L.) Mansf. All three species are from Indochina, and the former two species has distichous inflorescence; the latter has an imbricate inflorescence. Ngamriabsakul *et al.* (2004) also reported two clades; one with *B. basispicata* K. Larsen ex. Sirirugsa, *B. gelatinosa* K. Larsen, *B. longiflora* and *B.* aff. *longiflora*, and the other with *B. aurantiaca* R.M. Sm. and *B. cordata* R.M.Sm. All four species in the former group are from Indochina, and both of the latter group are from Borneo. To determine if the two types of inflorescence found in this study correspond consistently to the two possible phylogenetic groups, and to determine the taxonomy of the two groups, further studies on the morphology and molecular phylogeny of *Boesenbergia* using large samples from different regions and other related genera are essential.

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